Biosorption Activated Media (BAM) Filters for Water Quality Improvement: The Wekiva Parkway Upflow Filter

Design Training Expo

WEKIVA PARKWAY
Completing Central Florida's Beltway

Karen Snyder, Marty Wanielista, Alex George and Leo Anglero

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FDOT

University of Central Florida

bcc engineering

Florida Department of Environmental Protection

Presenters and Topics

- **Karen A. Snyder, P.E.** – FDOT partnership for current research and BAM implementation
- **Marty Wanielista, P.E., PhD, Professor Emeritus** – Overview of BAM design and application
- **Alex George, P.E.** – Wekiva Parkway Section 6 (FMN 238275-7) project overview, design and BAM implementation
- **Leo Anglero** – Lead FDEP reviewer for Wekiva Parkway Section 6 project, Q&A from a regulatory agency perspective

Partnership on BAM Research & Implementation

- FDOT Central Office
  - ✓ Research support for projects using BAM
  - ✓ Upcoming Drainage Design Guide (online)

- FDOT District 5
  - ✓ Blue Cove Lake, SR 35, SR 40, SR 528, Wekiva Parkway Section 6, Minuteman Causeway (LAP with Cocoa Beach)
  - ✓ Monitoring results of constructed projects

FDOT

Alternative Drainage FDOT Projects

- Potential BAM applications:
  - ✓ Basins requiring nutrient load reduction
    - ❑ Impaired basins
    - ❑ TMDL requirements
    - ❑ Adopted BMAPs
  - ✓ Projects with right-of-way constraints
  - ✓ Environmentally sensitive projects
  - ✓ Where it will provide a project benefit

BAM Use on FDOT Projects

- Wekiva Parkway Section 6 project (FPID 238275-7) – additional requirements
  - ✓ Project within Rock Springs Run and Wekiva River basins
  - ✓ Adopted TMDLs for TP and Nitrate-N
  - ✓ Final BMAP (Oct 2015)

Wekiva Section 6

- Traditional Stormwater Approach - Retention
- Different Approach Needed for Basin RS8-E
  - ✓ Within Rock Springs Run basin
  - ✓ Pond R/W already owned by FDOT
  - ✓ Type A/D soils, high SHGWT → wet detention
  - ✓ Eagle nest within pond R/W → buffer required
  - ✓ Limited options to meet net improvement criteria

Wekiva Section 6

- Alternatives evaluated:
  - ✓ Vegetative natural buffer
  - ✓ Stormwater reuse
  - ✓ Exfiltration
  - ✓ BAM applications -
    - ❑ In swales
    - ❑ Overland flow over roadside slopes (filter)
    - ❑ Upflow filter

What is Biosorption Activated Media (BAM)?

- Sorption is a physiochemical process that occurs with solid media to build-up or concentrate pollutant(s) onto the media (removes other chemicals as well)
- Activation occurs when the media and the working environment are specified to improve removal, sometimes by physical measures or biological means
- Thus BAM is a media for pollutant removal that has sorption properties in a specific environment

Some Measures of a Useful BAM for Nutrient Management

- Sorption (adsorption/absorption) properties
- Life expectancy (for removal is long)
- High surface area
- No biological toxic effects
- Ease of filtration
- Reasonably non-degradable
- Is sustainable or can be rejuvenated
- Right media, right place

Stormwater BMPs with BAM for:

- Green Roofs … TMDL and ERP credit
- Stormwater Reuse… TMDL and potable water replacement
- Swales… Nutrient Criteria and TMDL credit
- Pervious Pavements… Protect groundwater
- Wet Detention Pond Effluent…ERP & TMDL
- Bottom of Retention Basins… Protect groundwater
- Exfiltration… Protect groundwater
- Tree Wells, Lawn Gardens, Overland Flow, Depressed areas… ERP and TMDL credits, protect groundwater

Understand BMP Design and Effectiveness as Stand Alone or Combined in Series: Use BMPTRAINS Nutrient Model

Objectives: Water Capture, Pollution Control, Aesthetics

Stormwater BMP Treatment Trains [BMPTRAINS©]	CLICK HERE TO START

INTRODUCTION PAGE

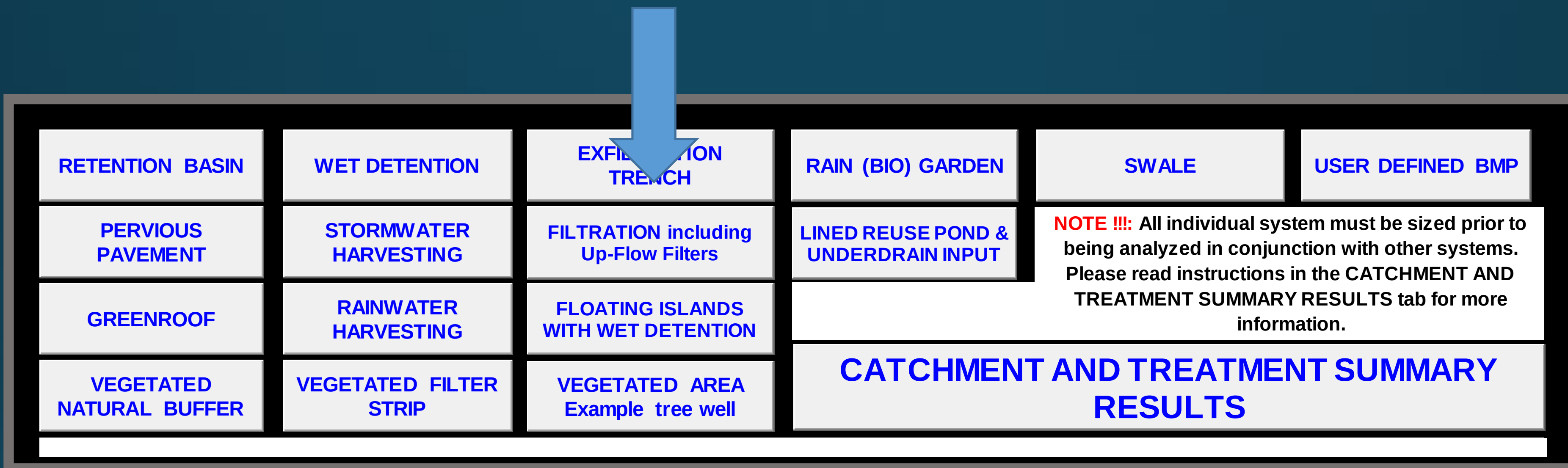
Model requires the use of Excel 2007 or newer

This program is compiled from stormwater management publications and deliberations during a two year review of the stormwater rule in the State of Florida.
Input from the members of the Florida Department of Environmental Protection Stormwater Review Technical Advisory Committee and the staff and consultants from the State Water Management Districts is appreciated.

The State Department of Transportation provided guidance and resources to compile this program. The Stormwater Management Academy is responsible for the content of this program.

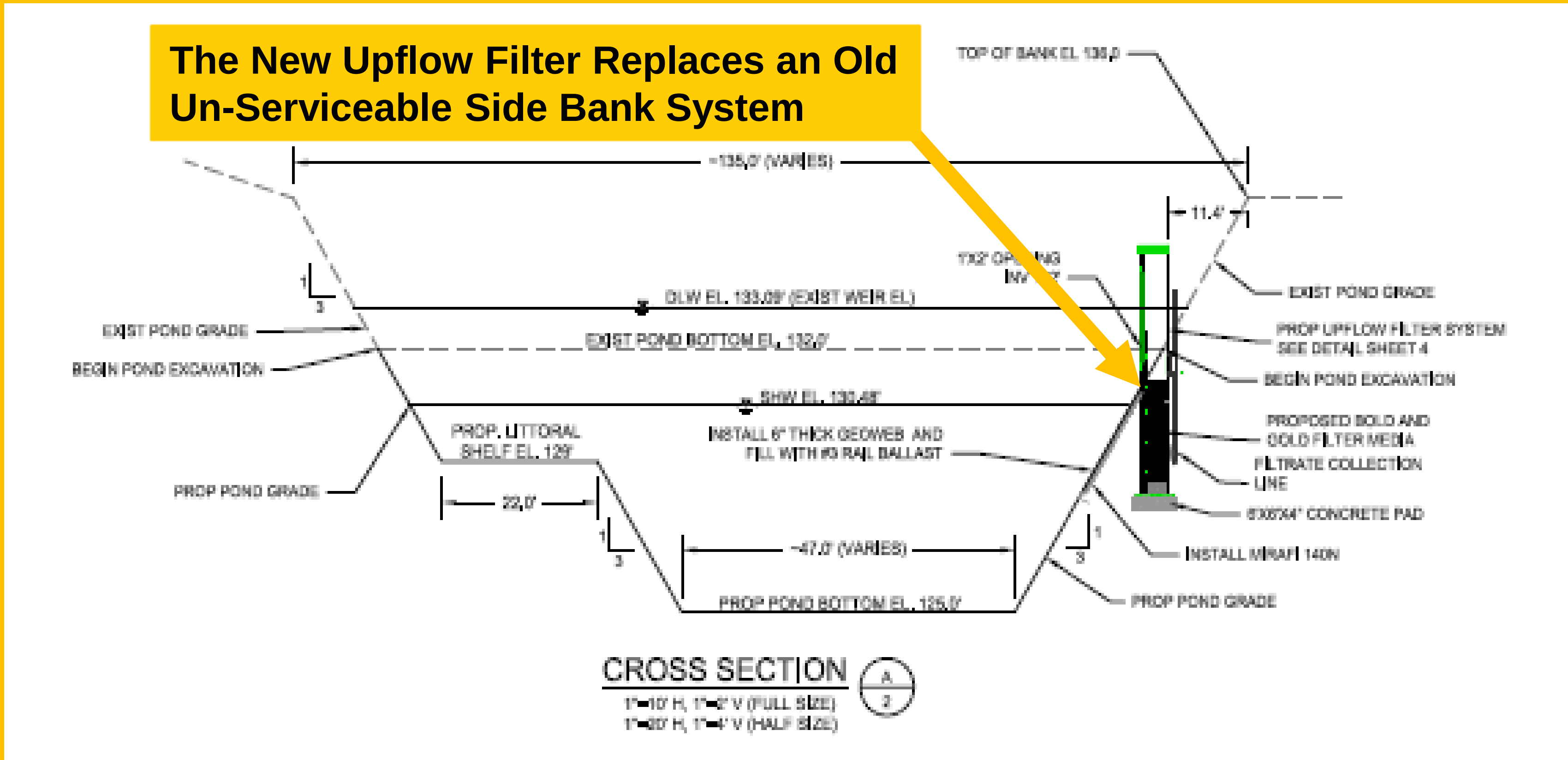
Available from **www.stormwater.ucf.edu** (no charge)

In-Line or Off-Line Upflow Filters



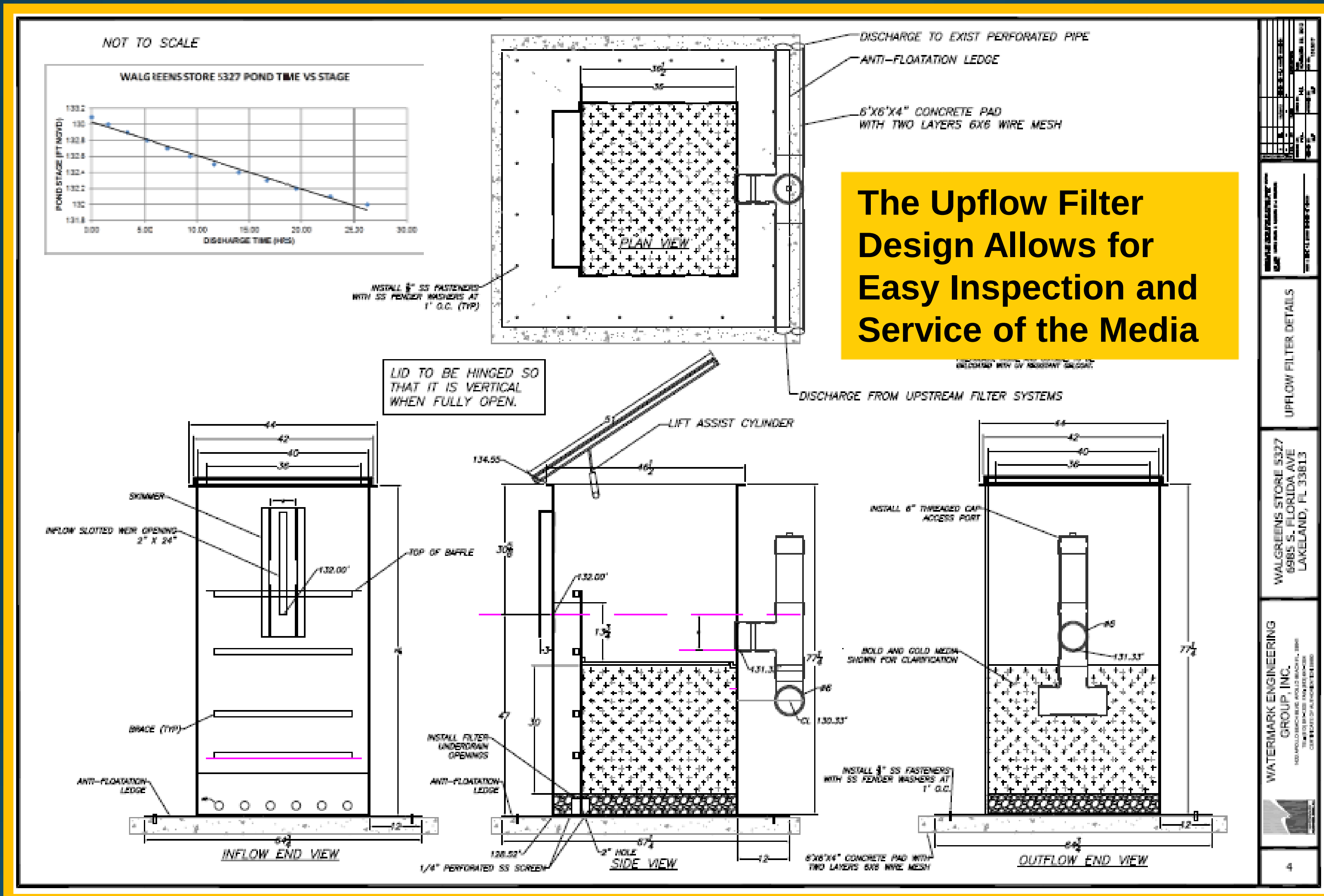
Can be underground or in the bank of a wet detention pond, thus does not “take” additional land purchases!

Example Pond Retrofit Design for Upflow Filter



WATERMARK
ENGINEERING GROUP, INC.

The Upflow Filter Design Allows for Easy Inspection and Service of the Media



WATERMARK
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Upflow Filter Installation by Suntree Technologies

Improved Treatment Using Upflow Filters with Wet Pond

Filters work to remove more

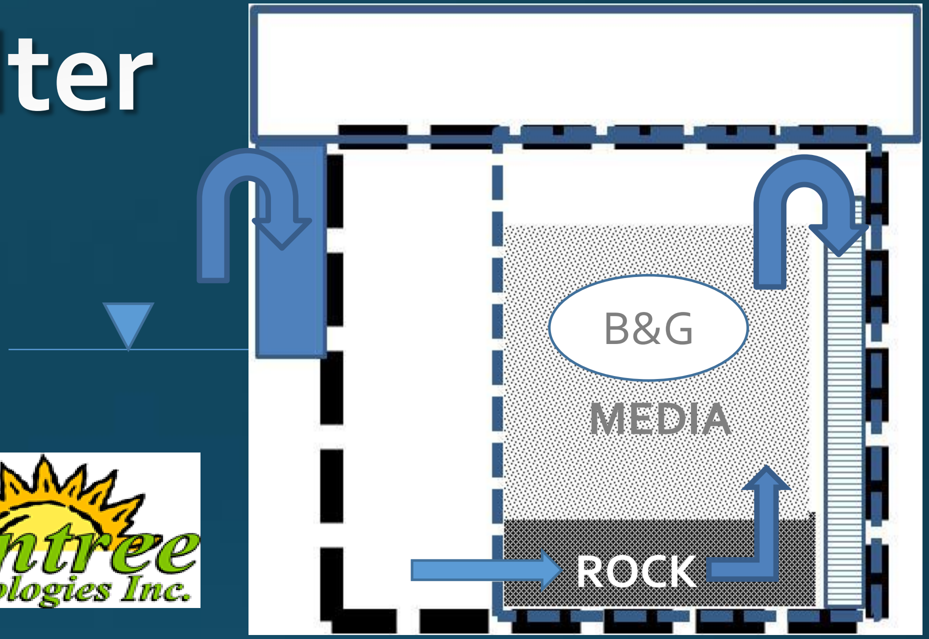
- Filters can be designed to remove nitrogen without media replacement
- For phosphorus, media replacement time is specified
- Can be used in BMP & LID “treatment train” applications with other treatment

UCF Stormwater Management Academy

WATERMARK ENGINEERING GROUP,

Upflow Input from Wet Detention to Filter

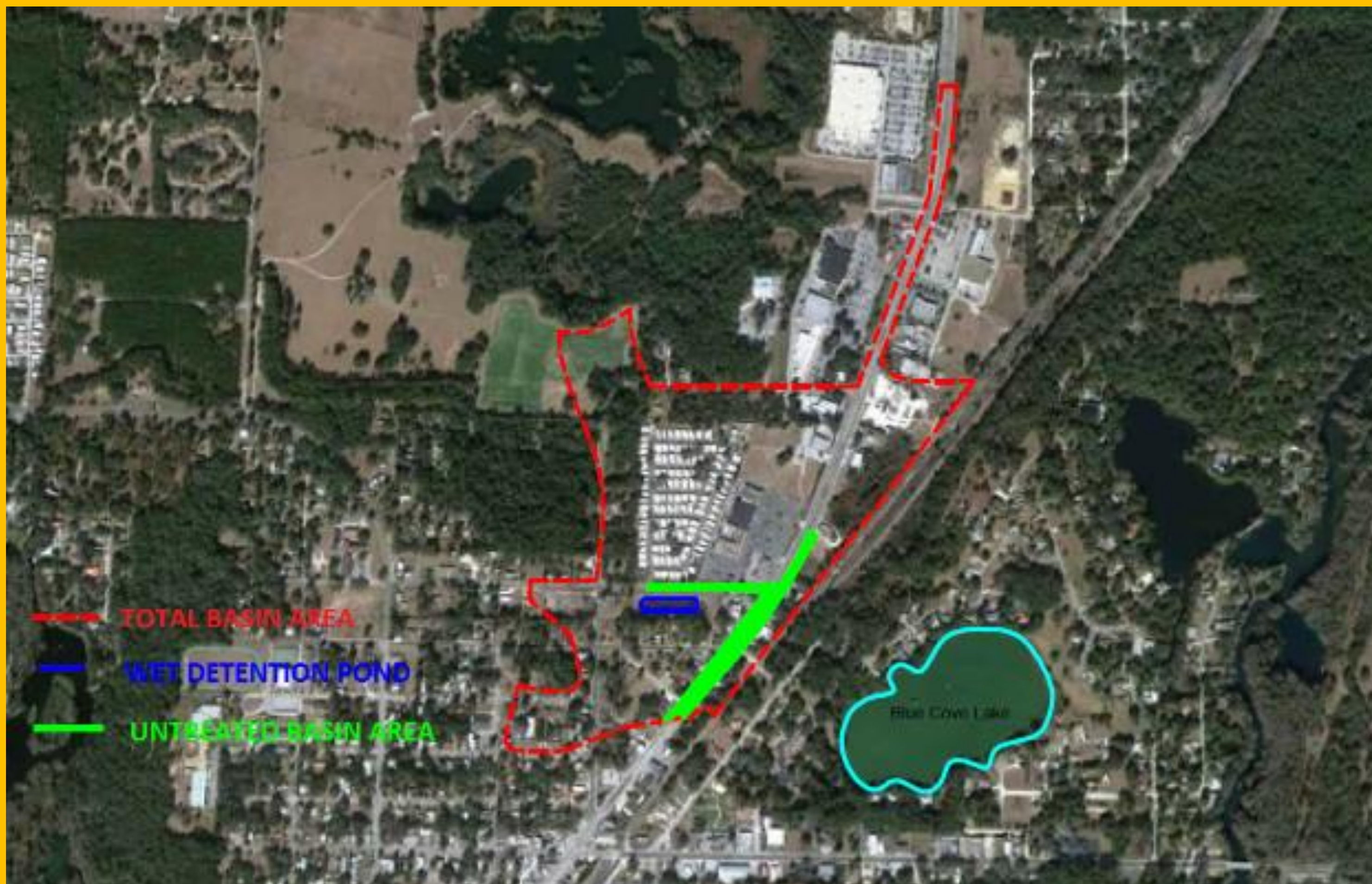
- Performance
  - ✓ Concentration
  - ✓ Averages based on field data
  - ✓ Average yearly based on 1" design for filter



Suntree Technologies Inc.

Parameter	TN	TP	TSS
Average Influent Concentration (mg/L)	1.83	0.73	42.7
Expected Average Pond Removal (%)	**38**	**63**	**79**
Average Pond + Filter Removal (%)	**70**	**72**	**91**
Average Annual System Performance	**67**	**70**	**89**

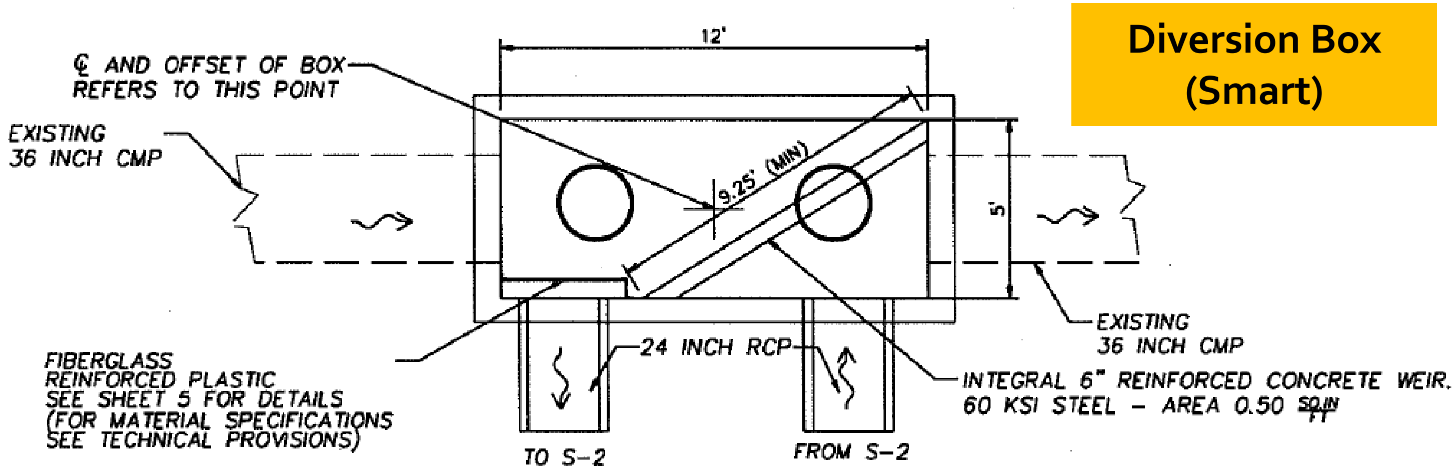
Off-Line Ultra Urban Filter
Blue Cove Lake- FDOT District 5



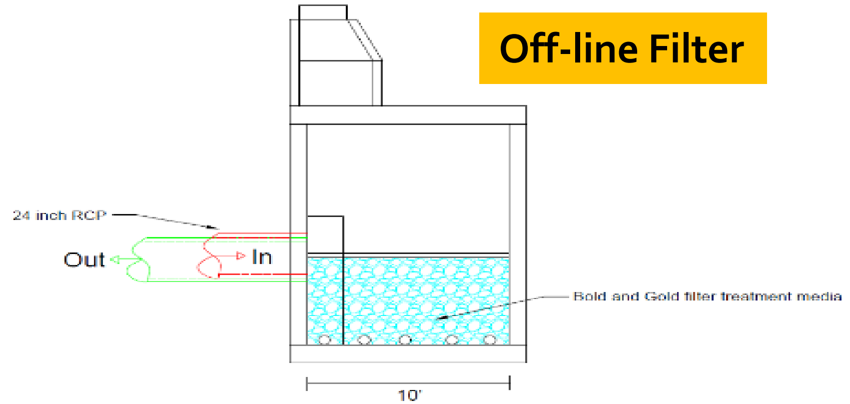
Blue Cove Lake – FDOT District 5

Reference: FDOT Project BDK78 977-19, May 2014
Demonstration: Bio Media for Ultra Urban Stormwater Treatment

Diversion Box (Smart)



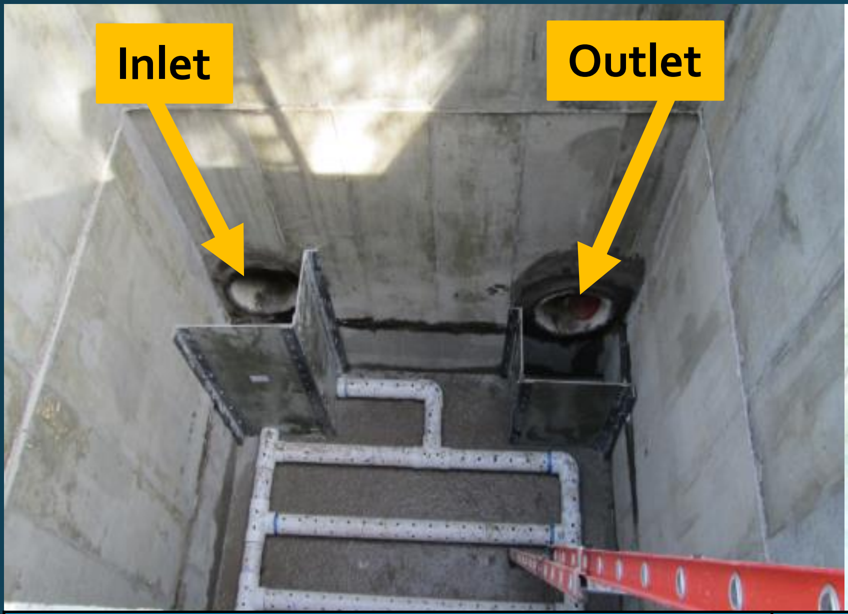
Off-line Filter

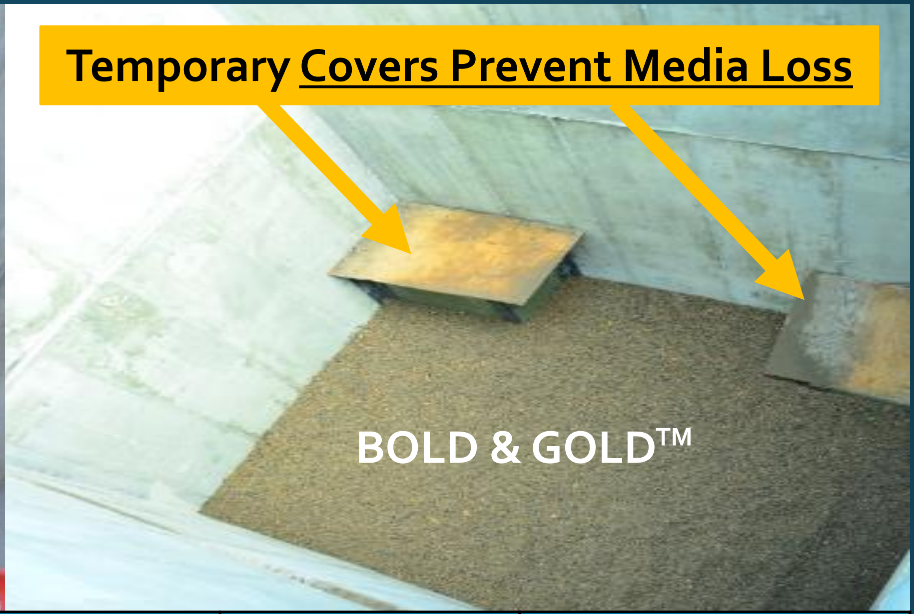


SECTION

Sampling Results and Installation Photos

70% of flow through filter (photo credit: FDOT Ocala)





Average Concentration and % Removal	TN	TP	TSS
Concentration from the Street (mg/L)	2.10	0.360	100
Concentration to the Filter (mg/L)	1.27	0.180	35
Concentration from the Filter (mg/L)	0.502	0.098	17
Average Filter Removal (%)	60	46	51
Overall Average Removal (%)	76	73	83
Annual Average Removal (%)	59	63	73

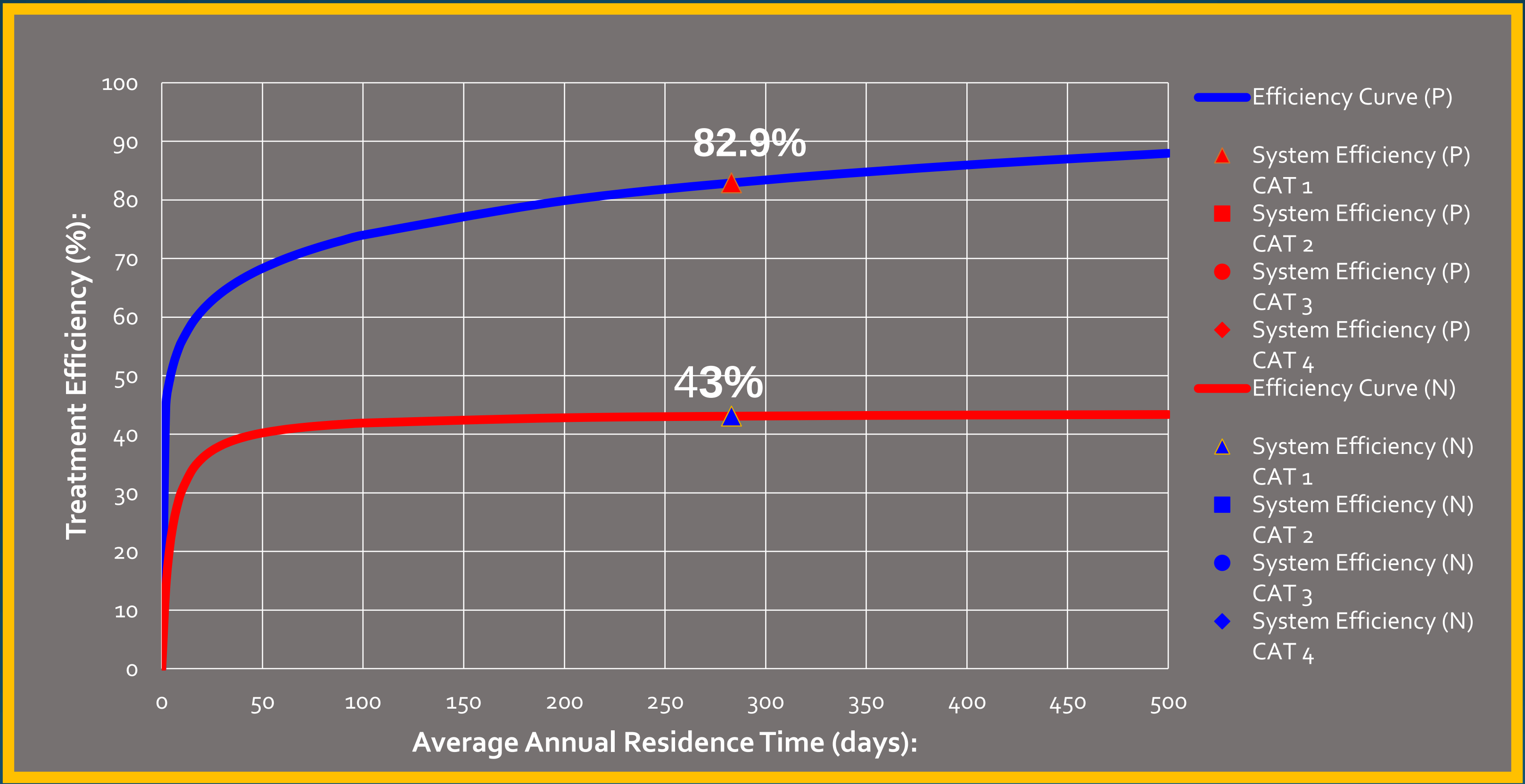
Basic Design Understanding

- Must provide treatment volume through the filter from each and every event up to that needed to capture the treatment design event
- The design storm capture is based on an average annual target removal (post=pre)
- Wet detention ponds rarely achieve high or (> 40%) TN removal
- As a factor of safety, the media treatment rate is half of the media permeability → use only 1 GPM/SF, not 2 GPM/SF
- Other BAM products have different filtration rates

Calculate Needed Removal and BMP sizes in a Treatment Train

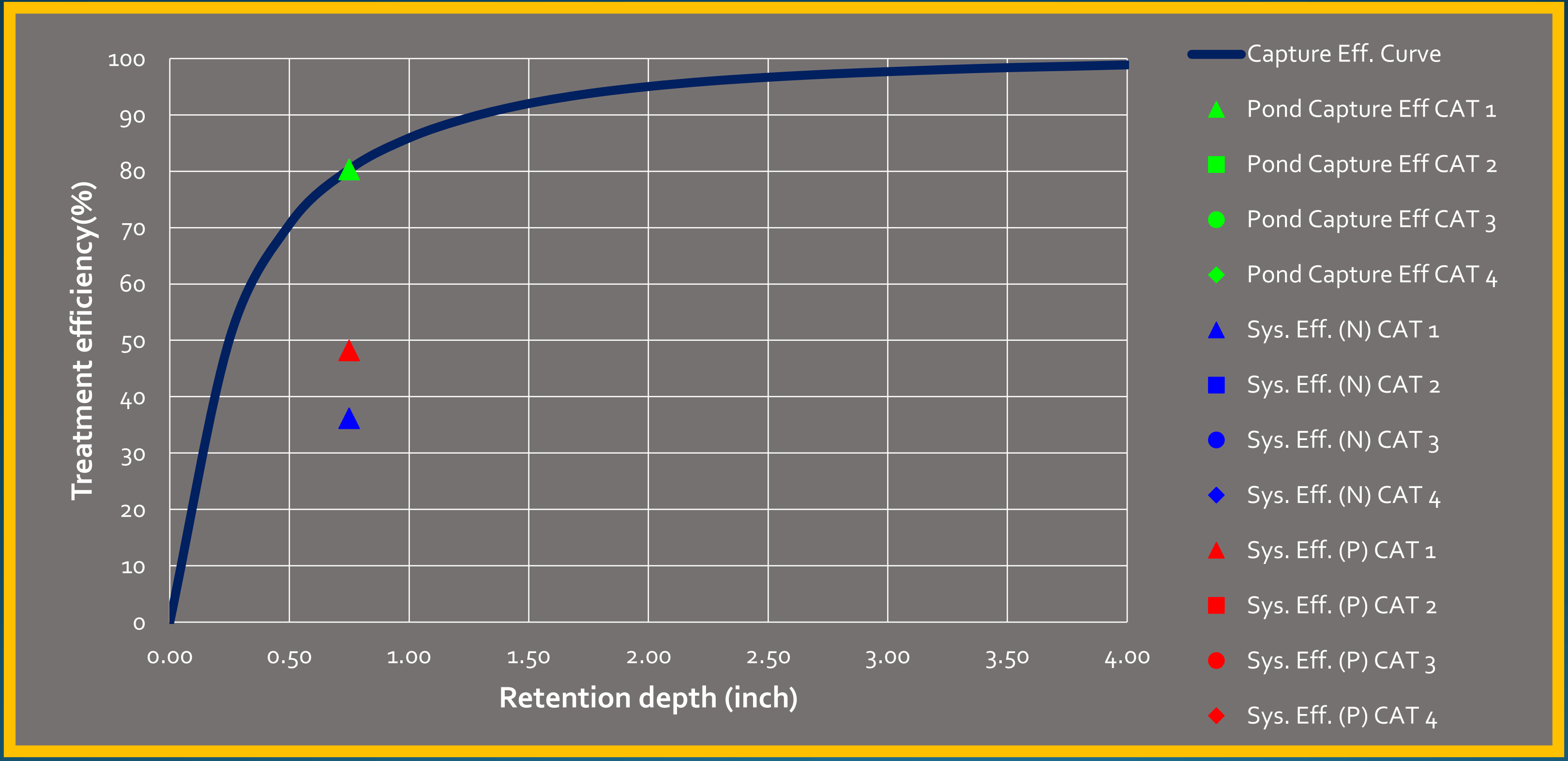
- Set removal as **Post = Pre** (e.g., 60% nitrogen removal as limiting) or **Fixed %** (e.g., 80%) or **assess the performance of a design**
- Calculate performance of BMP(s)
- BMPTRAINS is an acceptable model for pollutant loads
- Example: for the Wekiva Parkway, we want to use a wet detention pond and take advantage of concurrent flood protection (post discharge ≤ pre discharge) and achieve post=pre mass reductions for TN and TP

Treatment Volume for TN & TP in a Wet Detention Pond



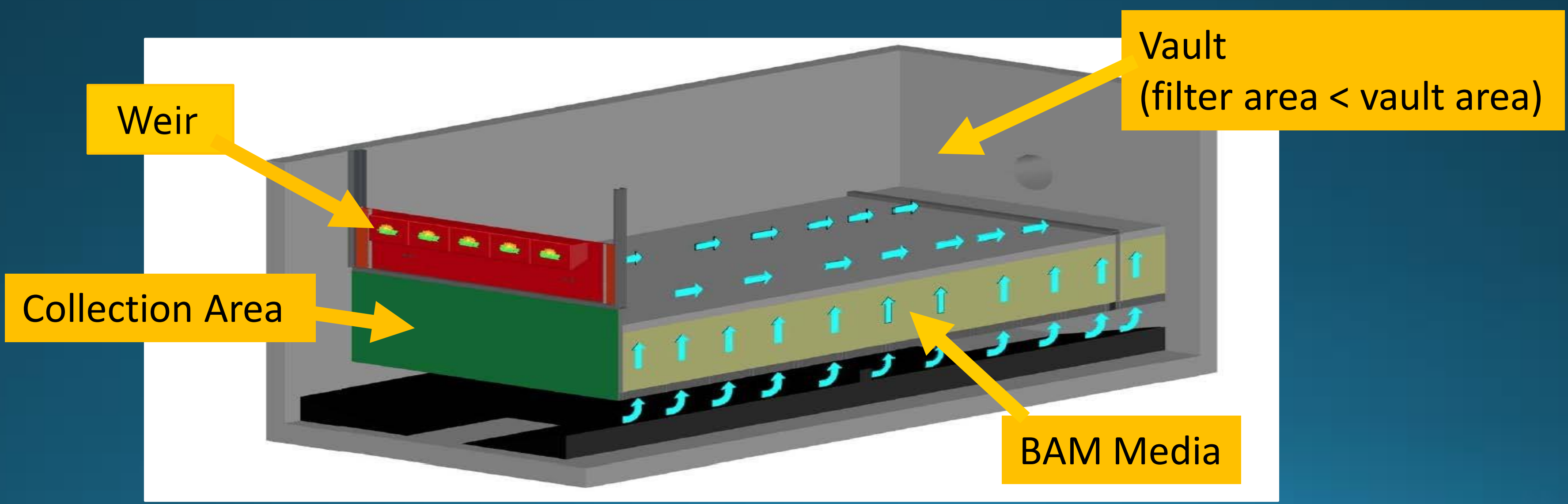
However as an example may need 60% nitrogen removal

Additional Treatment using Upflow Filter with BAM (0.75 inches of treatment volume)



Design Equation

- **Volume Treated = Runoff Volume at Design Storm Event**
- See hydrograph of volume treated
- One-half the volume treated in the first day is equal to the volume treated in the next two days
- Volume Treated = 1 GPM/SF x **SF of filter** x .0022288 CFS/GPM x 86,400 sec/day = CF Note: ½ volume treated in first day and ½ volume treated in the next two days

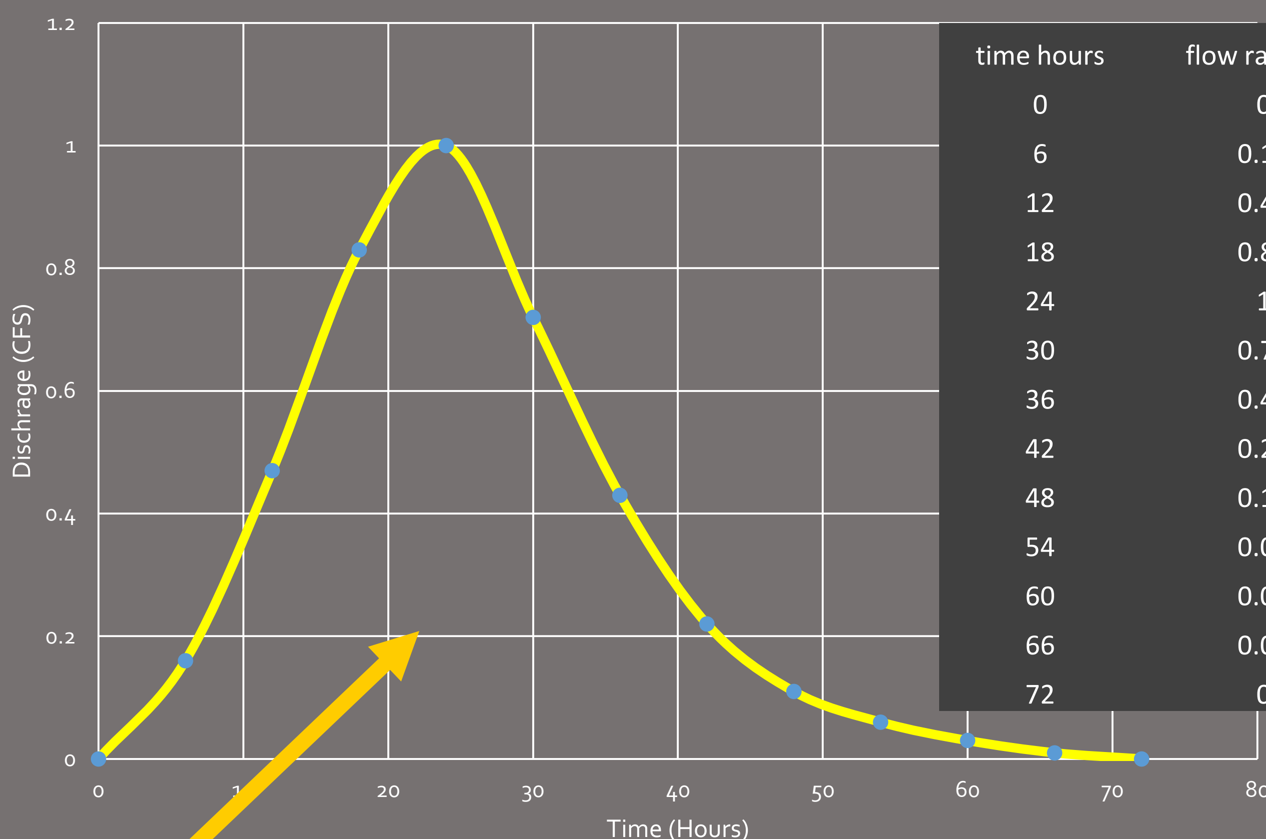


Sample Installation Drawing

with water spray nozzles for cleaning

Hydrograph (volume treated)

Example: one inch from 24 acres EIA



time hours	flow rate CFS	CF	Σ
0	0	0	
6	0.16	1728	1728
12	0.47	6804	8532
18	0.83	14040	22572
24	1	19764	42336
30	0.72	18576	60912
36	0.43	12420	73332
42	0.22	7020	80352
48	0.11	3564	83916
54	0.06	1836	85752
60	0.03	972	86724
66	0.01	432	87156
72	0	108	87264

Volume = 87,264 CF x12(in/ft) / 24 acres / 43,560(SF/acres) = 1.00 inches

What is EIA (Effective Impervious Area)?

- The area from which a depth of rain will result in the same depth of runoff.
- The Directly Connected Impervious Area (DCIA) is one example. By definition, the rain that "falls" on the DCIA all goes to runoff.
- BUT, what about the pervious areas from which rain results when the soil is saturated or the intensity of rain exceeds the infiltration rate? Estimation of that rainfall excess is typically done using the Curve Number Method (CN).
  - Example: CN=80, Runoff (R) starts when rain exceeds 0.5 inches.
  - And for a 2 inch filter design rain R= 0.56" thus EIA is 28% (0.56/2) and if the pervious area is 10 areas, the EIA for this area is 2.8 acres AT THE FILTER DESIGN RAINFALL DEPTH of 2 inches.

Life Expectancy for Phosphorus

- Givens: Data from the Wekiva Parkway Section 6 pond
  - Removal rate: 0.250 mg OP per gram of media using Bold & Gold data (lab derived)*
  - Average Yearly Flow: 3.08 million gallons (11,680,000 liters)
  - Target removal of OP is 0.030 milligrams per liter
  - Media Weight is 13,620 Kilograms
- Solution: How much can the media remove / (removal/year)
  - Service Years = Capacity of media (kg) / load per year (kg)
  - Service Years = [0.25 x 13,620/1,000] / [0.03 x 11,680,000/1,000,000] = **~ 10 (9.7) years**
  - This is a media depth of 2.5 feet (which is the minimum based on contact time)

* **Life expectancy is usually greater because of other physical, chemical and biological removal occurring in the "real" world.**

Design Equation (Continued)

- **Volume Generated** = **EIA (acres)** x Design Depth (inches) x 43560 SF/Acre x (1/12inches per foot) = CF
- Equate volume treated to volume generated, with rate = 1 GPM/SF and lumping the conversion factors
- 1 GPM/SF x **SF of filter** x .0022288 CFS/GPM x 86,400 sec/day = EIA (acres) x Design Depth (inches) x 43,560 SF/Acre x (1/12inches per foot)
- **Filter (SF) = [EIA (Ac) x Design Depth (inches)] x 18.857]**
- For the example and an EIA of 13.91 acres:

SF = EIA x depth x 18.857 = 13.91 x 0.75 x 18.857 = 197 SF

Note: One commercial 10’x25’ vault with filter = 200 SF

Design Chart Assistance

Inside Dim ftxft	Filter Area (SF)	Max CFS	Release (CF) 1st Day*	Release (CF) next 2 days	Total volume 3 days (CF)
4 x 4	14	0.0312	1347	1347	2695
4 x 8	30	0.0668	2887	2887	5775
5 x 10.5	42.5	0.0947	4091	4091	8181
6 x 12	54	0.1203	5197	5197	10395
6 x 15	72	0.1604	6930	6930	13860
8 x 17	107.5	0.2395	10347	10347	20694
10 x 20	164	0.3654	15785	15785	31570
10 x 25	200	0.4456	19250	19250	38500
12 x 25	240	0.5347	23100	23100	46200
	note: rate of maximum filtration is 0.002228 CFS/SF				
	* half the maximum				

Note:
filter area < vault area

Example Calculations for a 14 SF filter.

Column 3: Max CFS = 1 GPM/SF x 0.002228 CFS/GPM x 14 SF = 0.0312 CFS

Column 4: Release in 1^{st} day = 0.0312 CFS x 86,400 sec/day / 2 = 1347 CF

Column 5: Remaining half is released, thus 1347, extended value is 1347.49

Column 6: Sum of water released in 3 days (round off values)

General Recommendations for BAM

- Natural and recycled materials can be mixed and are being used in Florida and other parts of the U.S. for nutrient removal
- The media mix should include materials to ensure high moisture content if interested in biological removal
- Upflow filters with BAM (Bold &Gold™ as an example) do improve the water quality of discharges
- Design aids and charts are available for sizing the upflow filter (BMPTRAINS, etc.)

“Benefits” of using an Upflow Filter

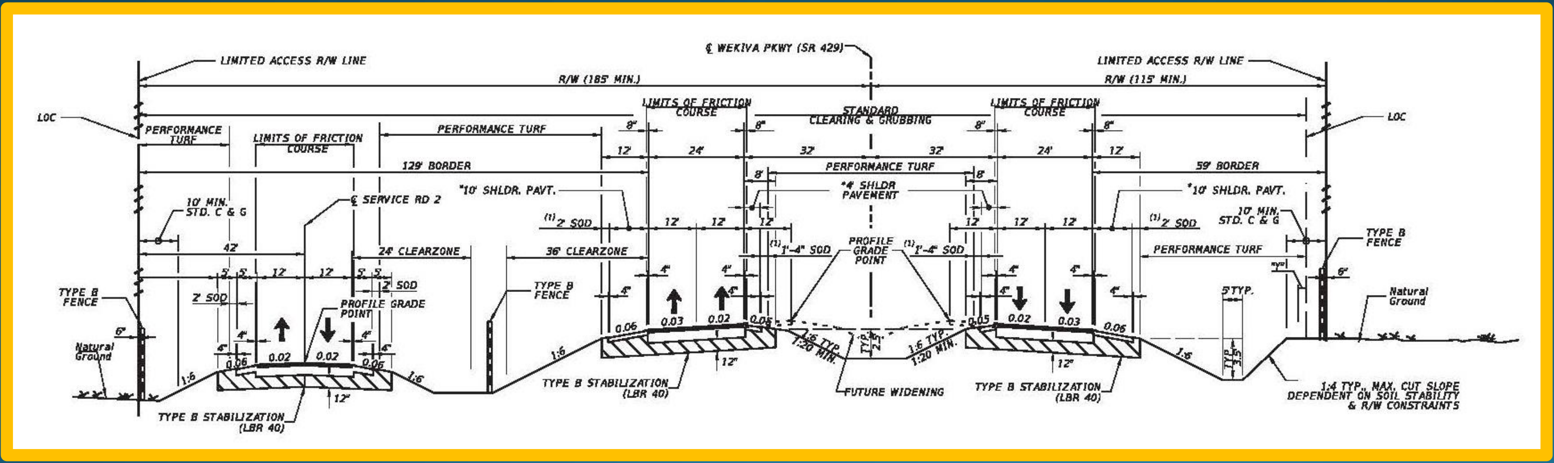
- After wet detention, there is improvement in the discharge water quality
- Longer operating life relative to the use of side underdrains
- Can be used for nitrogen and phosphorus removal
- Nitrogen removal is continuous, while phosphorus removal is limited by the volume treated
- Standard vault designs can be used and thus construction cost reduced

Wekiva Parkway Section 6

- Multiple project basins with adopted TMDLs
- Typical solution?...dry retention ponds or swales
- Basin RS8-E constraints
  - ✓ Pond right-of-way already owned by FDOT
  - ✓ Geotechnical characteristics of pond site
  - ✓ Roadway geometry
  - ✓ Close proximity of eagle nest to pond location

Wekiva Parkway Section 6

- Project Land Use Changes in Basin RS8-E
  - ✓ Existing Conditions: undeveloped
  - ✓ Proposed Conditions: SR 429 (future 6-lane), Service Rd (2-lane) and Multi-Use Trail
  - ✓ **<u>Large difference in pre vs. post nutrient loads</u>**

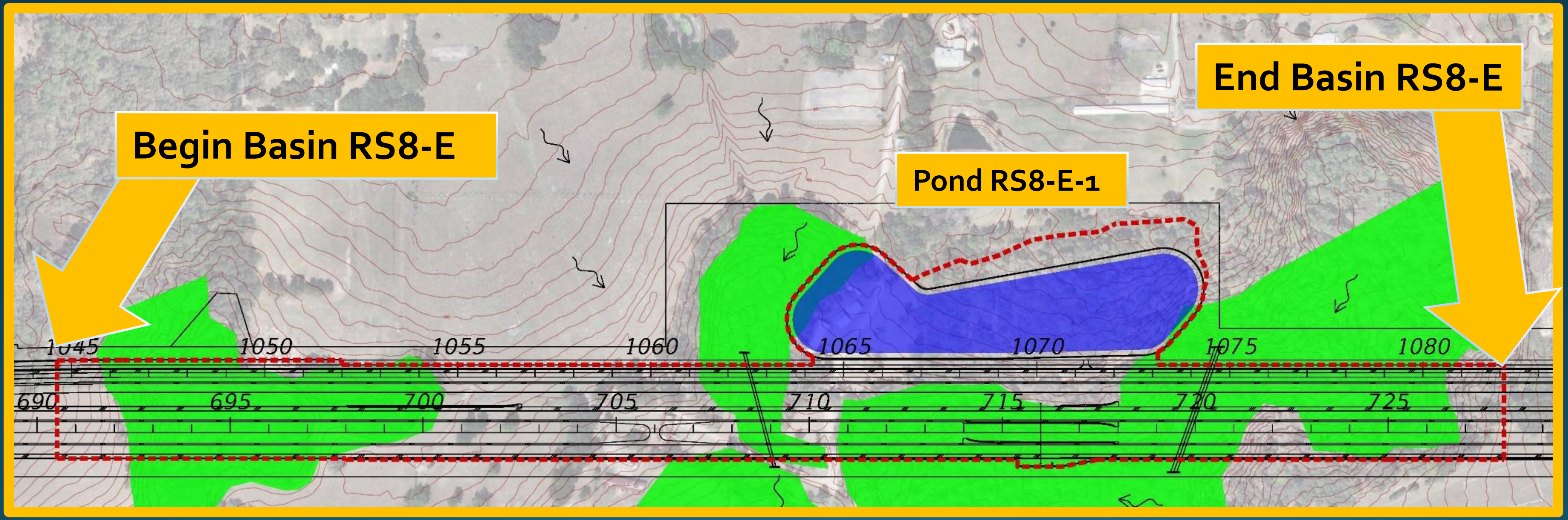


Wekiva Parkway Section 6

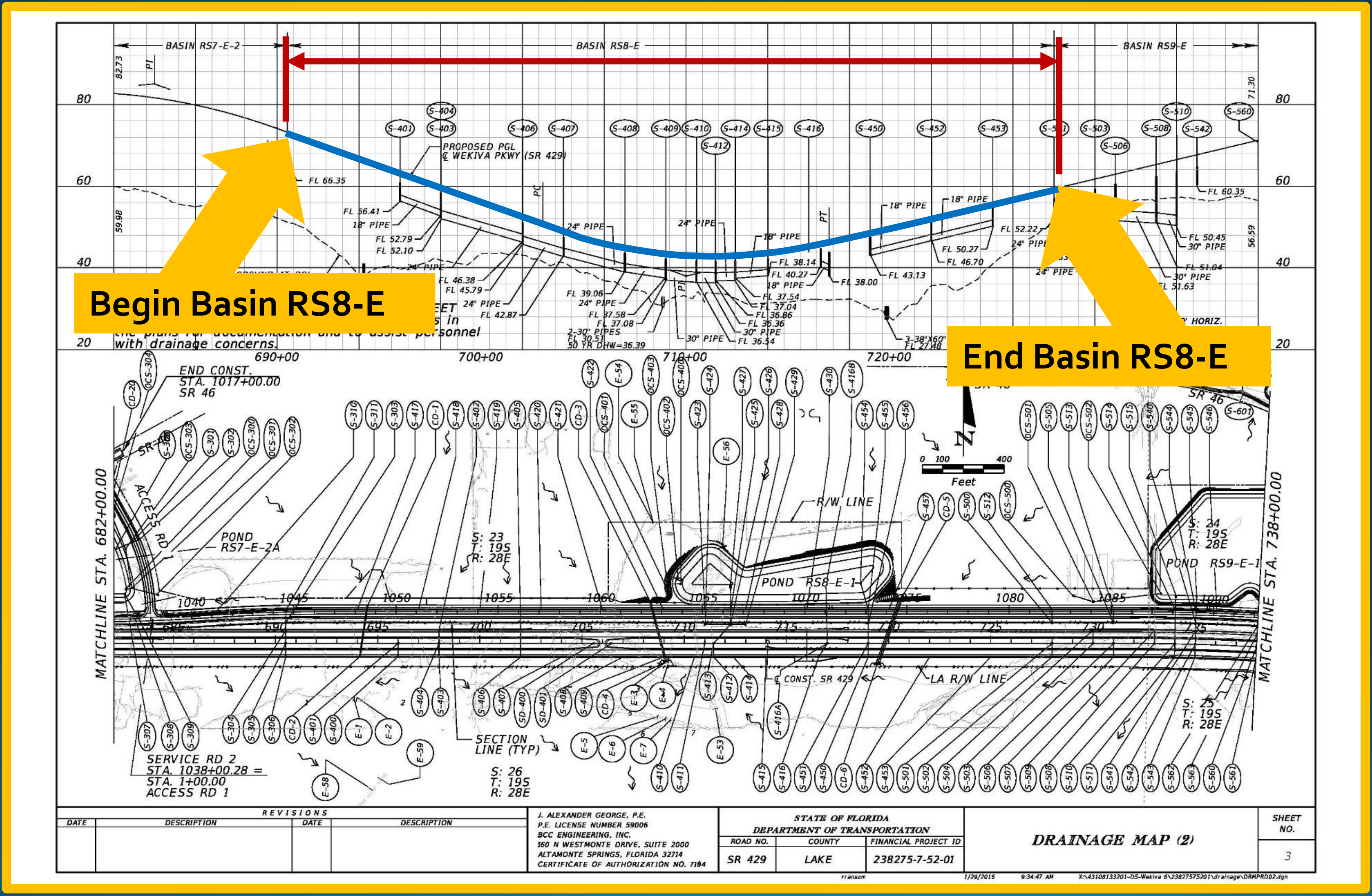
Drainage Boundary

Pond

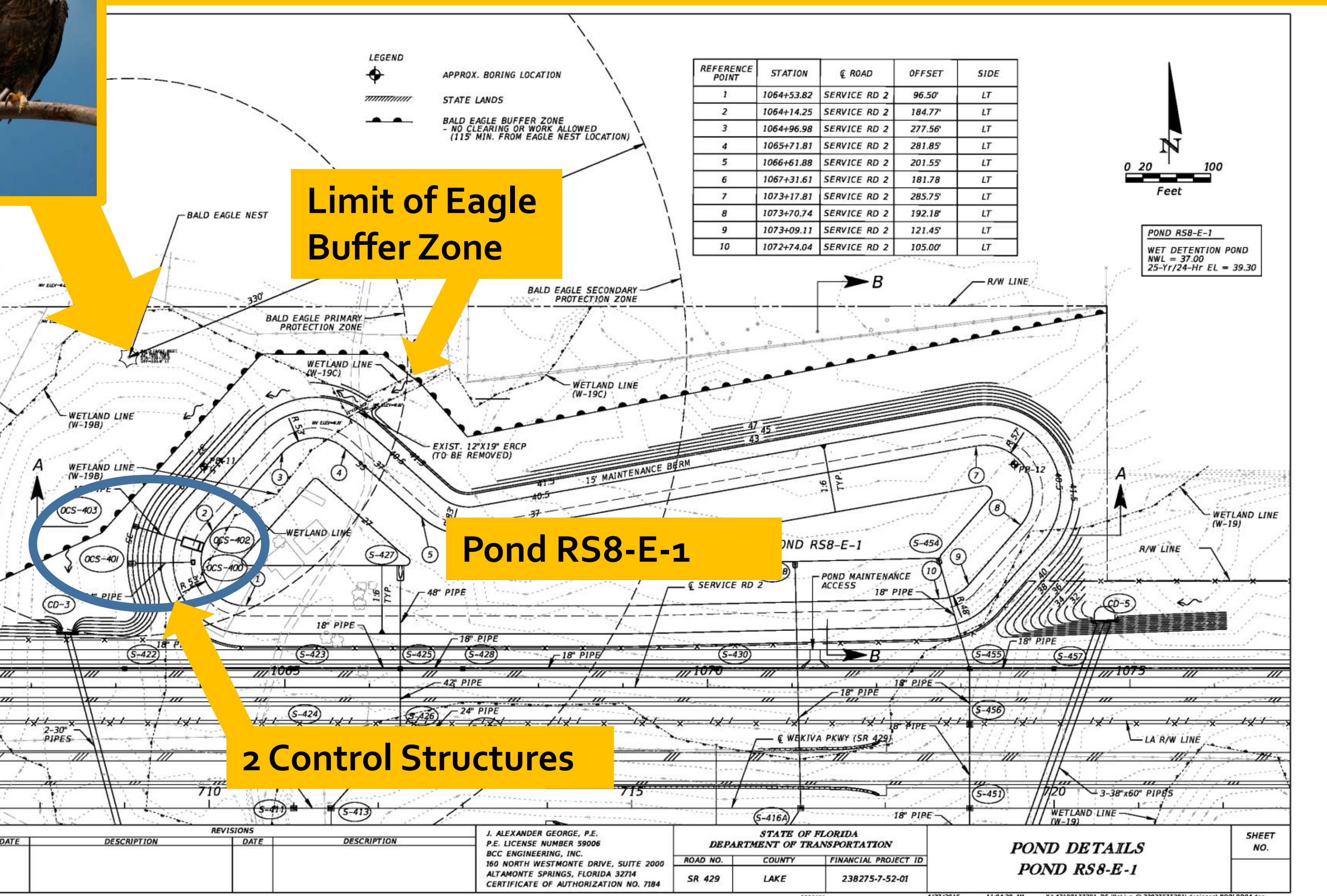
Wetlands



Wekiva Parkway Section 6



Wekiva Parkway Section 6



Wekiva Parkway Section 6

- Nutrient Removal Filter System (NRFS)
  - ✓ "Different name" for upflow filter with BAM
  - ✓ Design/sizing based on analysis by Dr. Wanielista
  - ✓ Nutrient Removal Report → part of ERP package
- Step 1: Pre vs. Post Nutrient Loads
  - ✓ Utilized BMPTRAINS
  - ✓ Post → traditional wet detention pond
- Step 2: Determine Nutrient Load Reduction Required
- Step 3: Size the BAM Filter Size Required

Wekiva Parkway Section 6

- From the Nutrient Removal Report:

Two methods for calculating the filter size are presented:

Method 1: Use Effective impervious area: The EIA is the wet area of the pond + the directly connected impervious area + the equivalent rainfall/runoff area of the non-directly connected area. The watershed area is 28.51 total acres, and includes 3.62 acres for a wet detention pond, 7.23 acres of directly connected impervious area, and 17.66 acres of non-directly connected area. The filter is designed to treat the runoff from each and every storm event up to and including 0.75 inches of rainfall. The runoff from the non-directly connected area is calculated using the Curve Number (CN) method and assumes a wet condition. The rainfall excess for a wet condition CN is thus 0.13 inches from the non-directly connected impervious area and the associated EIA is 17.66 x (0.13/0.75) = 3.06 acres. Thus EIA is the sum of all three areas or 3.62 +7.23 +3.06 = 13.91 acres. Using equation 1, the surface area of the filter is:

Filter (SF) = [EIA (Ac-Ft) x Treatment Depth (in) x 43560 (SF/Ac)] / [Filter Rate (GPM /SF) x .002228 (CFS/GPM) x 86400 (sec/day) x 12 (in/ft)].

Filter Area = [13.91 x 0.75 x 43560] / [1 x .002228 x 86400 x 12] = 197 SF

Method 2 Use Treatment Volume, this can also be a check on previous calculation:

Treatment volume = (0.75 in / 12 in/ft) x 3.62 Acres + (0.13 in / 12 in/ft) x 17.66 Acres + (0.75 in / 12 in/ft) x 7.23 Acres = 0.869 Ac-ft or about 37,854 CF.

The filter area is calculated as:

Filter (SF) = Volume (Ac-Ft) x 43560 (SF/Ac) /1 GPM/SF filter rate x (0.002228 CFS/SF) x 86400 sec/day. And Filter (SF) = 37,854 CF / (0.002228 x 86400) = 197 SF

From Table 1, the commercial size vault closest to the needed filter size is 200 SF.

Minimum filter size required

Wekiva Parkway Section 6

- Step 4: Incorporate NRFS into Post-Dev ICPR Model
  - ✓ Separate control structures → traditional control structure and NRFS work in tandem
  - ✓ Both control structures provide water quality drawdown
  - ✓ NRFS only provides min. treatment required to meet net improvement for nutrient loading
  - ✓ Head loss/rating curve for BAM filter
- Step 5: Design NRFS for BAM Filter Size Required
- Step 6: Check Against Water Quality Requirements
  - ✓ Water quality volume, drawdown, net improvement

Wekiva Parkway Section 6

- NRFS Rating Curve

Using:

$H = 1.0579e^{0.3517q}$

$A_f = 200$ sf

$Q = q \times A_f$

$\Phi Q = FS \times Q$

$FS = 2$

Where:

H = Head (in)

q = Unit Flow through upflow filter (gpm/sf)

A_f = Surface area of uplfow filter (sf)

Q = Total flow through upflow filter (gpm)

ΦQ = Factored total flow through upflow filter

FS = Factor of Safety

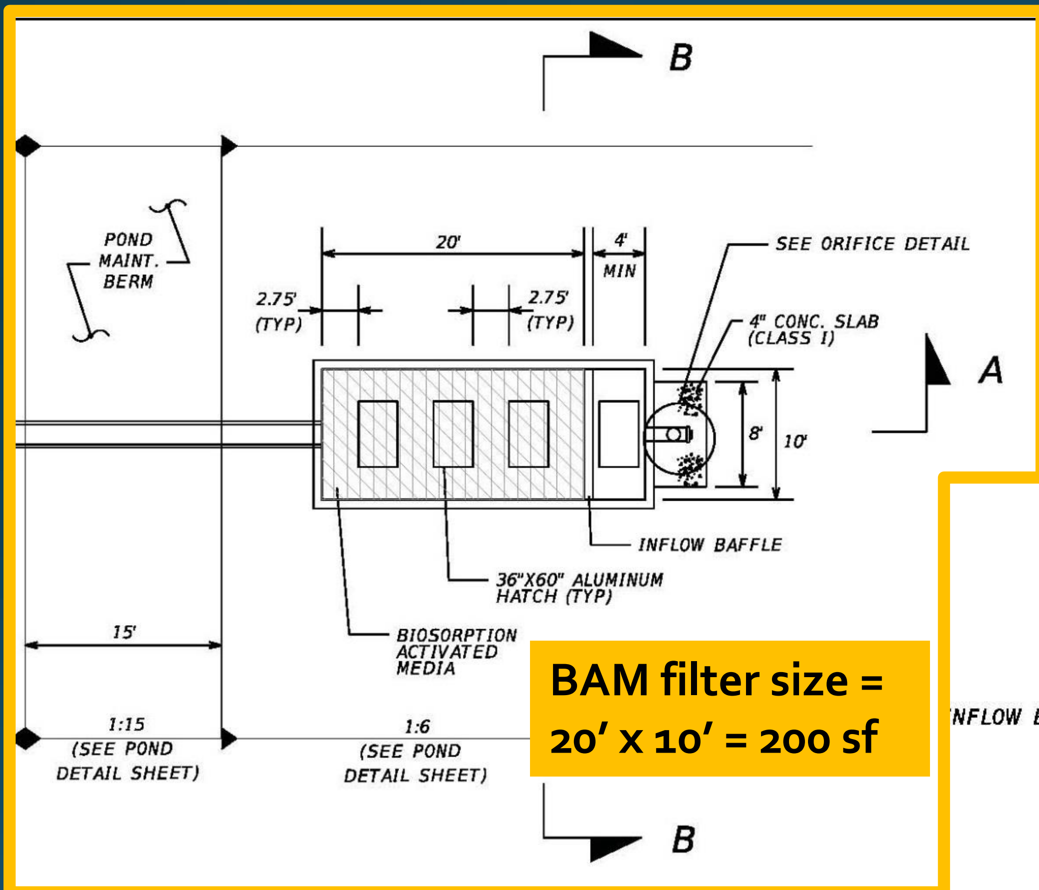
H (ft)	H (in)	q (gpm/sf)	q (cfs/sf)	Q (cfs)	ΦQ (cfs)
0	0	0.00	0.00	0.00	0.00
0.1	1.2	0.36	0.00	0.16	0.08
0.2	2.4	2.33	0.01	1.04	0.52
0.3	3.6	3.48	0.01	1.55	0.78
0.4	4.8	4.30	0.01	1.92	0.96
0.5	6	4.94	0.01	2.20	1.10
0.6	7.2	5.45	0.01	2.43	1.22
0.9	10.8	6.61	0.01	2.94	1.47
1	12	6.91	0.02	3.08	1.54
1.4	16.8	7.86	0.02	3.50	1.75
2	24	8.88	0.02	3.96	1.98
2.4	28.8	9.40	0.02	4.19	2.09
2.8	33.6	9.83	0.02	4.38	2.19
3.6	43.2	10.55	0.02	4.70	2.35
5.1	61.2	11.54	0.03	5.14	2.57
8.4	100.8	12.96	0.03	5.77	2.89

Head loss equation based on Dr. Wanielista's empirical data

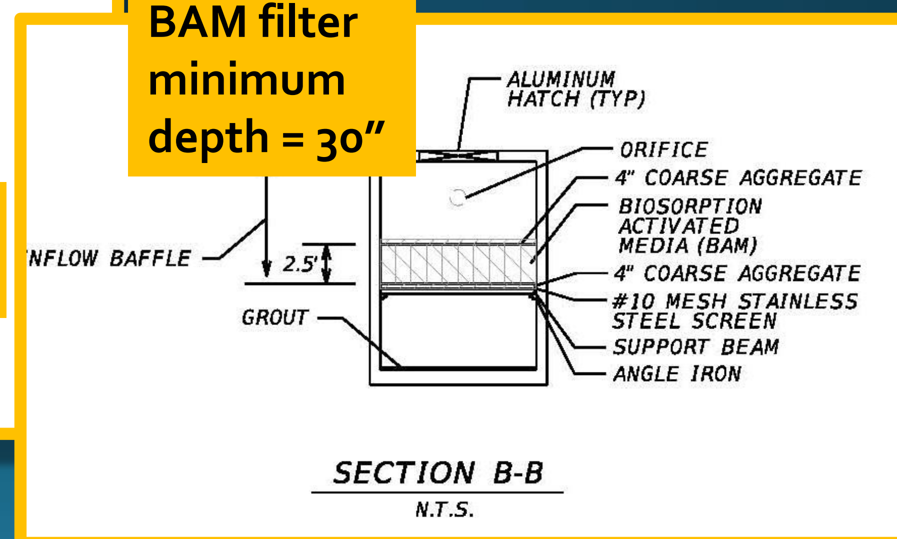
Rating table input into ICPR

Wekiva Parkway Section 6

- NRFS Control Structure (OCS-402)



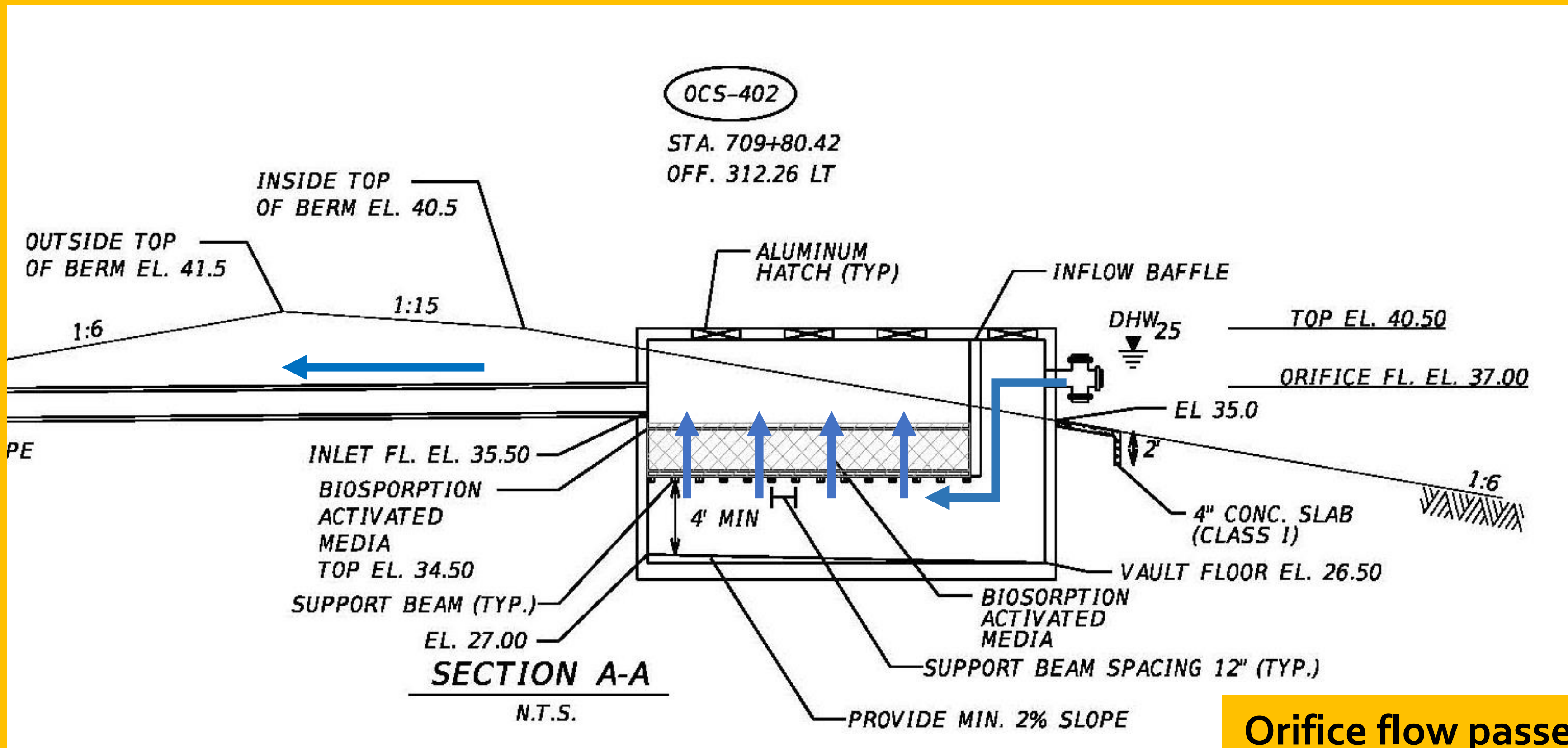
BAM filter size = 20' x 10' = 200 sf



BAM filter minimum depth = 30"

Wekiva Parkway Section 6

- NRFS Control Structure (OCS-402)



Orifice flow passes through BAM

Wekiva Parkway Section 6

- Pre vs. Post Nutrient Loading for Rock Springs Run Basin

Total Nitrogen (TN) (kg/yr)

	Basin					
Condition	RS7-E	ACR1	SC1-E & RS7-E-2A	RS8-E	RS9-E	Total
Pre-Development	2.90	0.74	3.55	13.13	1.50	21.82
Post-Development	0.00	0.06	1.15	18.06	1.72	20.99
Difference	-2.90	-0.68	-2.40	4.93	0.22	**-0.83**

Total Phosphorous (TP) (kg/yr)

	Basin					
Condition	RS7-E	ACR1	SC1-E & RS7-E-2A	RS8-E	RS9-E	Total
Pre-Development	0.14	0.04	0.17	0.63	0.07	1.05
Post-Development	0.00	0.01	0.14	0.54	0.21	0.90
Difference	-0.14	-0.03	-0.03	-0.09	0.14	**-0.15**

Conclusions

- Upflow filter with BAM - provides nutrient removal within R/W
- Wekiva Parkway Section 6:
  - ✓ First FDOT project using BAM under permit review
  - ✓ Special basin and TMDL criteria met
  - ✓ No RAI questions on NRFS
- BAM proven in the lab and field
  - ✓ Continued research and monitoring
  - ✓ Design aids available
- Up next…
  - ✓ TSPs for various BAM mixes & applications

Biosorption Activated Media Filters for Water Quality Improvement: The Wekiva Parkway Upflow Filter

Questions and Discussion

Thank You…